(19) Europäisches Patentamt
European Patent Office
Office européen des brevets

(11) EP 0 732 729 A2

(12) EUROPEAN PATENT APPLICATION

(43) Date of publication:
18.09.1996 Bulletin 1996/38

(51) Int. Cl.^{6}: **H01J 37/32**

(21) Application number: **96103803.1**

(22) Date of filing: **11.03.1996**

(84) Designated Contracting States:
DE GB IT

(30) Priority: **16.03.1995 JP 57472/95**

(71) Applicant: **HITACHI, LTD.**
Chiyoda-ku, Tokyo 101 (JP)

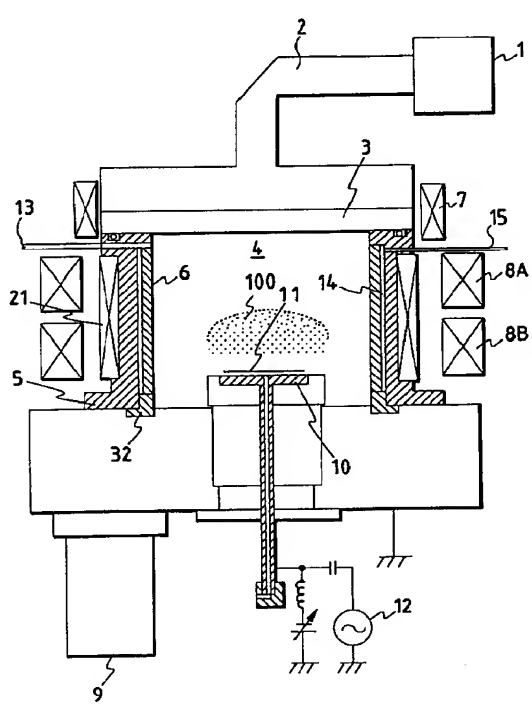
(72) Inventors:
- **Kanai, Saburo**
  Hikari-shi, Yamaguchi 743 (JP)
- **Takahashi, Kazue**
  Kudamatsu-shi, Yamaguchi 744 (JP)
- **Okamura, Kouichi**
  Tokuyama-shi, Yamaguchi 745 (JP)
- **Hamasaki, Ryoji**
  Hikari-shi, Yamaguchi 743 (JP)
- **Ito, Satoshi**
  Hikari-shi, Yamaguchi 743 (JP)

(74) Representative: **Beetz & Partner**
Patentanwälte
Steinsdorfstrasse 10
80538 München (DE)

(54) Plasma processing apparatus and plasma processing method

(57) A plasma processing apparatus comprises a plasma generating unit, a process chamber (4) capable of reducing its inside pressure, a gas supply system (13) for supplying a gas to the process chamber (4), a sample table (10) for holding a sample (11) and a vacuum pumping system, the process chamber comprises an outer cylinder (5) capable of withstanding depressurization and an inner cylinder (6) arranged inside the outer cylinder (5) through a gap (14), and a heater (21) and a temperature control means (22) are provided in the outer cylinder. A non-magnetic metallic material not containing heavy metals, or ceramic, carbon, silicon or quartz is used for the inner cylinder. The temperature of the inner cylinder is controlled to a desired value by using the heater and the temperature control means. By controlling the temperature of the inner cylinder, its surface temperature can be maintained at a desired value.

FIG. 1



EP 0 732 729 A2

Description

Background of the Invention

The present invention relates to a plasma processing apparatus and a plasma processing method and, more particularly, to a plasma processing apparatus and a plasma processing method suitable for processing such as etching a specimen using a high density plasma.

In a conventional plasma processing apparatus, as described, for example, in Kanno, T., Semiconductor Plasma Processing Technology, Sangyou-Tosho Company (1980), page 139, using a microwave plasma processing apparatus which has a quartz discharge chamber in a waveguide transmitting a microwave, plasma is generated in the discharge chamber by action of an outer magnetic field generated by a coil arranged in the outside of the discharge chamber and a microwave electric field. Thereby, processing such as etching of a surface of a semiconductor wafer can be performed using the plasma.

For a processing chamber in such a microwave etching apparatus, a non-magnetic and conductive material used as the waveguide is necessary to guide the microwave and to introduce the outer magnetic field in the processing chamber. Therefore, a metal such as aluminum (Al) or a stainless steel (SUS) is commonly used for the wall material of the processing chamber.

The metal such as a stainless steel or the like composing the wall surface of the processing chamber is worn and dispersed by the plasma, and the heavy weight metals contained in the metal become a contamination source.

A technology is disclosed in Japanese Patent Application Laid-Open No.4-229619 (1992) where a conductive coating film capable of protecting a metallic surface from chemical corrosion by a reaction gas used in a processing chamber is formed on the metallic inner surface. In this technology, a protective film is formed on the metallic inner wall surface of the processing chamber through coating since the metallic inner wall surface may be corroded when plasma etching is performed by using a halogen gas such as chlorine as the processing gas. Aluminum is used for the metal for the processing chamber, and TiN, InSn, SiC, TiC, TaC or the like is used for the coating material. The thickness of the coating film is 0.2 μm to 1 μm.

Further, a dry etching apparatus having opposed electrodes inside a chamber is disclosed in Japanese Patent Application Laid-Open No.63-138737 (1988) wherein the inside surface of the chamber is covered with an insulator material detachable from the chamber in order to keep a contaminated inner surface of the chamber clean. As the insulator material used is alumite, alumina thermal spraying, teflon, ceramic or the like.

The above conventional technology disclosed in Japanese Patent Application Laid-Open No.4-229619 (1992) can protect the metallic surface form chemical corrosion due to the reaction gas used in the processing chamber. However, as for the typical condition of the plasma etching process, it is clear that the temperature during plasma processing is limited within a relatively low temperature range from approximately 10°C to approximately 70°C. The reason why this temperature limitation is set seems that cracks may occur in the coating film on the aluminum surface due to the thermal expansion of the aluminum if the temperature of the aluminum composing the process chamber rises above 100°C during plasma processing. In order to avoid occurrence of cracks, the thickness of the coating film must be thinned. However, if the thickness of the film is thinned, the coating film cannot work its function since it is corroded out in a short time by the reaction gas generated during plasma etching. For example, a data according to an experiment conducted by the inventors shows that an SiC film is worn off at a speed of approximately 0.05 μm/minute during etching. This means that a coating film having a thickness of 0.2 μm to 1 μm is damaged and eliminated in several hours, that is, at a time when several hundreds of specimens have been processed. As a result, the metallic surface of the inner wall of the process chamber is exposed to the plasma and worn off by the plasma or altered its quality due to chemical reaction. The worn-off metal becomes a heavy metal contamination source and the quality-altered metallic wall degrades the characteristic of the process chamber.

On the other hand, in the invention disclosed in Japanese Patent Application Laid-Open No.63-138737 (1988), a contaminated isolator member is dismounted from a chamber and cleaned, and then re-mounted in the chamber to be used again. However, in a system where an insulator member is mounted onto the inner surface of a chamber, there is a problem in that the plasma processing characteristic largely fluctuates because the temperature of the mounted insulator member fluctuates during plasma processing.

Summary of the Invention

An object of the present invention is to provide a plasma processing apparatus and a plasma processing method in which the characteristic of plasma processing is stabilized over time by preventing the inner surface of the process chamber from altering its quality and from becoming a heavy metal contamination source, and by maintaining the temperature of the inner surface of the process chamber at a given temperature.

The present invention is characterized by a plasma processing apparatus comprising a plasma generating unit, a process chamber capable of reducing its inside pressure, a process gas supply unit for supplying a gas to the process chamber, a specimen table for holding a specimen, and a vacuum pumping unit, wherein

the process chamber comprises an outer cylinder having capability of withstanding reduced pressure,

an inner cylinder arranged inside the outer cylinder through a gap, and a temperature controlling means for maintaining the temperature of the inner cylinder within a given temperature range.

The present invention is also characterized by, in the plasma processing apparatus described above, the process chamber comprises an outer cylinder having capability of withstanding reduced pressure, an inner cylinder arranged inside the outer cylinder through a gap, a temperature controlling means arranged in the outer cylinder, and a heat transmission means for transmitting heat between the outer cylinder and the inner cylinder arranged in the gap.

Further, the present invention is characterized by a plasma processing method of processing a specimen using a plasma processing apparatus comprising a plasma generating unit, a process chamber capable of reducing its inside pressure, a process gas supply unit for supplying a gas to the process chamber, a specimen table for holding a specimen, and a vacuum pumping unit, the process chamber comprises an outer cylinder having capability of withstanding reduced pressure, an inner cylinder arranged inside the outer cylinder through a gap, a temperature controlling means arranged in the outer cylinder, and a heat transmission means for transmitting heat between the outer cylinder and the inner cylinder arranged in the gap, wherein plasma processing is performed to the specimen while the temperature of the inner cylinder is being kept within a given temperature range.

Still further, the present invention is characterized by, in the plasma processing method described above, the inner cylinder is made of a non-magnetic material not containing heavy metals, or made of a material selected from the group of ceramic, carbon, silicon, quartz and metal, and plasma processing is performed to said specimen while the temperature of said inner cylinder is being kept within a given temperature range.

According to the present invention, since the inner cylinder used as the inner wall of the process chamber which is made of a material not containing heavy metals such as a ceramic, a metallic surface such as aluminum composing the outer cylinder does not exposed during processing a wafer. Therefore, the wall never becomes any heavy metal contamination source by being worn or changed it quality by plasma. On the other hand, since the thermal conductivity of the inner cylinder is lower than that of the outer cylinder, the temperature of the inner cylinder, that is, the surface temperature of the process chamber may be raised up to 200°C to 350°C during etching process if the temperature is not controlled. In the present invention, since the temperature of the inner cylinder is controlled to a desired temperature, for example, a desired temperature between 100°C to 350°C, the surface temperature of the process chamber can be kept to a desired temperature and the etching characteristic is also kept stable.

Further, it is also possible to stabilize the process by controlling the surface temperature of the inner cylinder in a desired pattern.

Furthermore, in a case of employing such a material composing the cylinder that the inner side surface of the material is worn bit by bit by plasma, since the inside surface of the inner cylinder is always renewed to a new surface, there is no worry about contamination due to the quality change of the inside surface and accordingly there is no time-change in the characteristic of the process chamber. In addition to this, since the inner cylinder does not contain any heavy metals, there is no worry that the inner cylinder becomes a contamination source even if it is worn.

Brief Description of the Drawings

FIG.1 is a partially cross-section vertical front view showing an embodiment of a microwave plasma processing apparatus in accordance with the present invention.

FIG.2 is an enlarged view showing the main part of the temperature controller for the inner cylinder shown in FIG.1.

FIG.3 is a graph showing the function of the temperature controller of FIG.1.

FIG.4 is a graph showing the relationship between gap pressure P and temperature difference in the temperature control.

FIG.5 is a vertical cross-sectional view showing a second embodiment of a microwave plasma processing apparatus in accordance with the present invention.

FIG.6 is a transverse cross-sectional view showing the main part of the plasma processing apparatus of FIG.5.

FIG.7 is a vertical cross-sectional view showing a third embodiment of a parallel plate plasma etching apparatus in accordance with the present invention.

FIG.8 is a cross-sectional view showing an example of a magnetron RIE apparatus to which the present invention is applied.

FIG.9 is a cross-sectional view showing an example of a plasma processing apparatus to which the present invention is applied, and the plasma processing apparatus is of an external energy supplying discharge type, and particularly of an induction coupling discharge type and a non-magnetic field type.

FIG.10 is a cross-sectional view showing an example of a plasma processing apparatus to which the present invention is applied, and the plasma processing apparatus is of an external energy supplying discharge type, and particularly of an induction coupling discharge type and a magnetic field type.

FIG.11 is a cross-sectional view showing an example of a plasma processing apparatus to which the present invention is applied, and the plasma processing apparatus is of an external energy supplying discharge type, and particularly of an induction coupling discharge type and a magnetic field type.

FIG.12 is a vertical cross-sectional view showing an example of a sample to be processed with an apparatus in accordance of the present invention, and the sample is a resist attached oxide film.

FIG.13 is a graph showing the relationship between number of processed wafers and temperature of the inner cylinder.

FIG.14 is a cross-sectional view showing an embodiment of a sample table cover portion of a plasma processing apparatus to which the present invention is applied.

Detailed Description of the Preferred Embodiments

Embodiments of the present invention will be described in detail below, referring to the accompanying drawings.

FIG.1 is a partially cross-section vertical front view showing an embodiment of a microwave plasma processing apparatus in accordance with the present invention, and FIG.2 is an enlarged view showing the main part. The reference character 1 is a magnetron as a microwave oscillator source, and the reference character 2 is a guide tube for microwave. The reference character 3 is a quartz plate for supplying a microwave to a process chamber 4 by vacuum sealing the process chamber 4. The process chamber 4 is composed of an outer cylinder 5 made of, for example, high purity aluminum (Al) and capable of withstanding depressurization, and an inner cylinder 6 arranged inside the outer cylinder and made of ceramic such as silicon carbide (SiC) or the like. Since the inside surface of the process chamber is formed of an insulator and the outer side is formed of a conductor, the process chamber 4 also serves as a waveguide. The reference character 7 is a first solenoid coil for supplying a magnetic field, and the reference character 8 (8A, 8B) is a second solenoid coil. The process chamber 4 is evacuated to vacuum by a vacuum pump connected to a vacuum chamber 9. The reference character 10 is a sample table for mounting a wafer 11 to be processed, for example, to be etched, and connected to a high frequency power source 12. The reference character 13 is a process gas supplying system which supplies a process gas for performing processing such as etching, film forming or the like into the process chamber 4.

There is a gap G14 having an interval nearly 0.1 to 2 mm between the inner cylinder 5 and the outer cylinder 6, and a heat transfer gas for temperature control is introduced into the gap through a gas supply system 15. The gas supply system 15 has a gas source 16, a pressure control valve 17, a pressure detector 18, a pressure command instruction means 19 and a controller 20. The pressure P between the gap 14 is detected by the pressure detector 18 and opening of the pressure control valve 17 is controlled so as to keep the pressure P at a desired value.

The inner cylinder 6 is supported by a supporter 32. In order to replace the inner cylinder when its surface is worn a certain amount, the inner cylinder is detachably supported by the outer cylinder.

A heater 21 for heating the process chamber 4 is arranged around the outer cylinder 5, and the temperature T of the inner cylinder 6 is detected by a temperature detector 23 and a controller 22 controls the temperature of the outer cylinder 5 to a temperature T_0. The heater 21 works to keep the temperature T of the inner cylinder 6 by keeping the temperature T_0 of the outer cylinder 6 and the pressure of the gap at preset values.

During plasma processing, the pressure of the process chamber 4 is adjusted to a preset process pressure by introducing a process gas into the process chamber 4 from the gas supply system 13 at a given flow rate while vacuum evacuating by the vacuum pump. Further, the temperature T_0 of the outer cylinder 5, the temperature T of the inner cylinder 6 and the pressure P of the gap 14 are controlled by the heater 21, the gas supply system 15 and the temperature controller 22.

On the other hand, the wafer 11 to be processed is mounted on and held to the sample table 10, the magnetron 1 and the first and the second coils 7, 8 being switched on, a microwave being guided to the process chamber 4, and then plasma 100 is generated in the process chamber 4 to etch the wafer 11.

According to the present invention, since no metallic surface such as aluminum is not exposed as the inside wall of the process chamber 4 and accordingly there is no phenomenon that a metal is worn and varied its quality, the wall is cannot become a heavy metal contamination source to the wafer 11.

On the other hand, the SiC inner surface constructing the inner cylinder 6 is worn by plasm 100 bit by bit. However, the SiC cylinder does not contains any heavy metal, there is no worry that the cylinder becomes a contamination source even if it is worn. On the contrary, since the inner surface of the inner cylinder is always renewed to a new surface by being worn, there is no worry about contamination due to varying in the quality of the inside surface and accordingly the characteristic of the process chamber 4 hardly varies with time. The worn SiC component is exhausted from the process chamber 4 by the vacuum pump.

The temperature of the inner cylinder is increased by heat generated in the process chamber during etching process. If it is not controlled, the temperature T of the inner cylinder will reaches up to 200°C to 350°C or higher. On the other hand, the etching characteristic in a plasma etching process strongly affected by the temperature of the inside surface. In other words, since reaction between the inner cylinder 6 and the etching gas varies depending on the change in the surface temperature of the inner cylinder 6 and causes fluctuation in etching gas environment, the etching characteristic is not stabilized. For example, since the temperature change of the inner surface 6 fluctuates the component and the accumulation amount of accumulated materials

on the wall and the change in the reaction speed with the wall fluctuates the component in the plasma, the etching characteristic is not stabilized.

In the present invention, the surface temperature T of the inner cylinder is controlled to a desired value in the range of 100°C to 350°C, preferably 150°C to 300°C, by controlling the temperature T_0 of the outer cylinder 5 using the heater 21 and the pressure P in the gap 14. According to the present invention, since the surface temperature T of the inner cylinder 6 is kept at a preset value, the etching characteristic becomes stable. Further, since the surface temperature T of the inner cylinder 6 is kept at a preset value and the etching speed to the inside surface of the inner cylinder 6 is stabilized, wearing rate of the surface of the inner cylinder 6 worn by plasma also becomes constant. Thereby, the characteristic of the process chamber 4 becomes stable.

FIG.3 shows the function for controlling the temperature of the inner cylinder 6 by the temperature controller 22. As an example, the figure shows a case where the temperature T of the inner cylinder 6 is approached to T_0 by keeping the temperature of the outer cylinder 5 to T_0.

In this case, as shown in FIG.4, the temperature difference between T and T_0 can be decreased by increasing the pressure P in the gap 14. In more detail, in a case where the distance of the gap 14 is 1 mm, He gas is supplied to the gap 14 and the gas pressure is controlled to 10 Torr, when the heat input to the inner cylinder 6 is 0 to 300 W, the temperature of the inner cylinder 6 can be kept in 150°C ± 20°C for the outer cylinder temperature of 150°C.

An optimum temperature for a desired temperature of the inner cylinder differs depending on the combination of kind of the inner cylinder, film quality to be processed, kind of process gas, discharge condition and so on.

In a case where, for example, a resist attached oxide film sample shown in FIG.12 is processed by using a CF family gas as the process gas and using quartz as the material for the inner cylinder, when the temperature of the inner cylinder is not controlled, the temperature of the inner cylinder is gradually increased by receiving heat from the plasma and saturated to a certain temperature as number of processed samples is increased, as shown in FIG.13. Therein, although change in the etching speed of the oxide film is small, the etching speed of the resist is gradually decreased as the temperature of the inner cylinder increases and then the etching speed of the resist is stabilized when the temperature of the inner cylinder is saturated.

On the other hand, by keeping the temperature of the inner cylinder to the saturating temperature of FIG.13 in advance, a stable etching speed for the resist can be obtained from the first sheet of the processed samples.

In a case where the temperature of the inner cylinder is continuously being kept at an initial temperature, not at the saturating temperature shown in FIG.13, the etching speed for the first sheet of the processed samples can be obtained.

Heat transfer capability of the gap is higher when the gap 14 is narrower, but the effect for the temperature control can be kept up to the gap of 2 mm.

The material of the inner cylinder 6 in this embodiment is necessary to be a non-magnetic material because of a microwave discharge using a magnetic field, and not to be varied its quality by plasma and not to contain any heavy metals. As the materials satisfying these conditions, there are materials such as carbon (C), silicon (Si), quartz (SiO), alumina (Al_2O_3) and so on. However, aluminum may be employed depending on the content of plasma processing.

The inner cylinder 6 is required to have a mechanical strength above a certain value and durability. That is, the SiC cylinder forming the inner cylinder 6 in the embodiment must have such a thickness as to have a mechanical strength capable of withstanding an outer force acting during plasma processing, and as to have durability capable of withstanding large amount of wafer processing while it is worn by plasma.

On the presumption that the SiC wall is worn at the rate of approximately 0.05 μm every minute by etching and practical number of wafers processed by one inner cylinder is several ten thousands, the SiC wall thickness of 2 to 10 mm is sufficient.

In the embodiment shown in FIG.1, it is preferable that the surface temperature of the quartz plate 3 is also controlled to 100°C to 350°C in the same manner as in the temperature control of the inner cylinder 6.

FIG.5 is a vertical cross-sectional view showing another embodiment of a microwave plasma processing apparatus in accordance with the present invention. The process chamber 4 is constructed with an outer cylinder 5 formed of a highly pure aluminum and an inner cylinder 6 formed of a ceramic arranged in the outer cylinder. The inside surface of the process chamber 4 is reversely taper shaped, and the inner cylinder 6 is truncated cone shaped. There is a gap 14 between the outer cylinder 5 and the inner cylinder 6. In the gap 14, a corrugated plate 30 made of aluminum is arranged, and the corrugated plate 30 contacts to the outer cylinder 5 and the inner cylinder 6 with spring force. A heater 21 for heating is arranged in the periphery of the outer cylinder 5. The lower portion of the inner cylinder 6 is supported on a support member 32 through a spring 31. There is also a spring 33 in the upper portion of the inner cylinder 6. The contact force between the outer cylinder 5 and the inner cylinder 6 is increased by these springs 31, 33 and the corrugated plate 30. The springs 31, 33 also have a function to absorb difference of thermal expansion between the outer cylinder 5 and the inner cylinder 6.

In this embodiment, the function of the inner cylinder 6 formed of SiC is the same as that in the previous embodiment. This embodiment is characterized by that heat transmission between the outer cylinder 5 and the

inner cylinder 6 is performed by combination of a contact heat transmission by the corrugated plate 31 and gas heat transmission by the gas inside the gap 14. According to the embodiment, the etching characteristic can be stabilized since the surface temperature T of the process chamber , that is, the inner cylinder can be kept at a temperature close to the temperature T_0 of the outer cylinder 5.

In the embodiments in FIG.1 to FIG.5, the temperature of the inner cylinder 6 may be detected not directly if it can be detected indirectly. However, the following effects can be obtained by attaching a temperature detector 23 to the inner cylinder 6.

(1) By making the pressure in the gap 14 variable or by finely adjusting the temperature of the outer cylinder in order to control the temperature of the inner cylinder 6 more accurately, controllability of the inner cylinder temperature can be improved.
(2) By monitoring the temperature of the inner cylinder 6, it is possible to output an alarm signal such as stopping plasma processing or to quit plasma processing when the temperature of the inner cylinder 6 exceeds a preset range.

In the embodiments in FIG.1 to FIG.5, it is described that a heater is used as the temperature control function for the outer cylinder. However, by recirculating a temperature controlled liquid to the outer cylinder, it is possible to widen the temperature control range from a cooled state below room temperature to a heated state, and accordingly controllability of the inner cylinder temperature can be improved.

FIG.7 shows anther embodiment of a parallel plate plasma etching apparatus to which the present invention is applied. This apparatus has a vacuum chamber of process chamber 4 which is a substantially closed metallic reaction chamber constructed by an outer chamber 40, an upper plate 41, a side wall 42 and a bottom plate 43. In The vacuum chamber there is provided a pair of parallel plate electrodes facing each other, the anode is ground to the inside wall of the outer chamber 40 and the cathode 47 is mounted on the outer chamber 40 through an insulator 46, and there is also provided a high frequency power source 48 for supplying a high frequency energy to the cathode. Further, there are provided a vacuum pump connecting part 44 for partially evacuating the process chamber 4 and a reaction gas supply source for supplying a reaction gas to the process chamber 4 through a valve controlled pipe 45. A wafer 11 to be etched is mounted on the cathode 47.

An inner cylinder 49 made of SiC is formed on the inside surface of the outer chamber 40, that is, on the upper plate 41, the side wall 42 and the bottom plate 43. There is a gap 50 between the outer chamber 40 and the inner cylinder 49, and a heat transfer gas for temperature control is introduced in the gap from a gas supply system. The gas supply system has a gas source, a pressure control valve, a pressure detector, a pressure command instruction means and a controller, and operates so as to maintain the pressure P in the gap 50 at a preset value, as the same as in the embodiment of FIG.1. A heater 51 for heating the process chamber 4 is arranged in the outer periphery of the outer chamber 40, and the temperature T_0 of the outer cylinder is controlled by a temperature controller through the heater 51 and the temperature T of the inner cylinder 49 can be kept to a desired value, as described in the embodiment of FIG.1. A temperature detector 23 may be attached to the inner cylinder 49.

With such a construction, by maintaining the temperature of the inner cylinder 49 at a preset value during plasma etching, it is possible to obtain the effect that the metal is not worn nor varied its quality by plasma by the same function as in the embodiments described above. Further, since the inside surface of the inner cylinder 49 is always renewed to a new surface, there is no worry about contamination due to varying in the quality of the inside surface. Furthermore, since the temperature of the inner cylinder 49 is maintained at a preset value, it is possible to preform a stable plasma processing. Herein, in the case of the parallel plate type etching apparatus, it is not necessary to limit the material of the inner cylinder to a non-magnetic material.

The present invention can be applied to other apparatuses having different plasma generating mechanisms. Examples of the application are shown in FIG.8 to FIG.11.

FIG.8 shows an example of a magnetron RIE apparatus having a magnetron 80 to which the present invention is applied. A process chamber 4 of a vacuum chamber has a side wall 42, a sample table 10 for mounting a wafer 11 and a high frequency power source 48 for supplying a high frequency energy to the electrode of the sample table 10. Further, There are a connection part to a vacuum pump for partially evacuating the process chamber 4 and a reaction gas supply source for supplying a reaction gas to the process chamber 4 through a valve controlling pipe 13.

An inner cylinder 49 made of SiC is formed on the inside surface of the side wall 42. There is a gap between the side wall 42 and the inner cylinder 49, and a heat transfer gas for temperature control is introduced in the gap from a gas supply system 15. The gas supply system has a gas source, a pressure control valve, a pressure detector, a pressure command instruction means and a controller, and operates so as to maintain the pressure P in the gap 50 at a preset value, as the same as in the embodiment of FIG.1. A heater 51 for heating the process chamber 4 is arranged in the outer periphery of the side wall 42, and the temperature T_0 of the side wall 42 is controlled by a temperature controller 22 through the heater 51 and the temperature T of the inner cylinder 49 can be kept to a desired value, as described in the embodiment of FIG.1.

With such a construction, by maintaining the temperature of the inner cylinder 49 at a preset value during plasma etching, it is possible to perform a stable plasma

processing by the same action described in the above embodiment. Further, it is possible to obtain the effect that the metal is not worn nor varied its quality by plasma. Further, since the inside surface of the inner cylinder 49 is always renewed to a new surface, there is no worry about contamination due to varying in the quality of the inside surface.

FIG.9 shows an example of a plasma processing apparatus to which the present invention is applied, and the plasma processing apparatus is of an external energy supplying discharge type, and particularly of an induction coupling discharge type and a non-magnetic field type. A process chamber 4 is surrounded by a silicon plate 90 and a quartz chamber 92. The reference character 91 is a heated antenna member and the reference character 95 is an upper heater. In this embodiment, by maintaining the temperature of the quartz chamber 92 at a preset value during plasma etching, it is possible to perform a stable plasma processing by the same action described in the above embodiment. Further, it is possible to obtain the effect that the metal is not worn nor varied its quality by plasma. Further, since the inside surface of the quartz chamber 92 is always renewed to a new surface, there is no worry about contamination due to varying in the quality of the inside surface.

FIG.10 shows an example of a plasma processing apparatus to which the present invention is applied, and the plasma processing apparatus is of an external energy supplying discharge type, and particularly of an induction coupling discharge type and a magnetic field type. The reference character 105 is a bell jar and the reference character 110 is an antenna. A process chamber 4 of a vacuum chamber has an inner cylinder 112, an outer cylinder 114, a sample table 10 for mounting a wafer 11 and a high frequency power source 48 for supplying a high frequency energy to the electrode of the sample table 10. Further, There are a connection part to a vacuum pump for partially evacuating the process chamber 4 and a reaction gas supply source for supplying a reaction gas to the process chamber 4 through a valve controlling pipe. Furthermore, there are provided a heater 116 and a cooling water passage 120 for performing temperature control by heating and cooling the outer cylinder 114.

There is a gap between the inner cylinder 112 made of SiC and the outer cylinder 114, and a heat transfer gas for temperature control is introduced in the gap from a gas supply system 15. The gas supply system has a gas source, a pressure control valve, a pressure detector, a pressure command instruction means and a controller, and operates so as to maintain the pressure P in the gap at a preset value. The temperature T_0 of the outer cylinder 114 is controlled by a temperature controller through the heater 116 and the temperature T of the inner cylinder 112 can be kept to a desired value.

With such a construction, by maintaining the temperature of the inner cylinder 112 at a preset value during plasma etching, it is possible to perform a stable plasma processing by the same action described in the above embodiment. Further, it is possible to obtain the effect that the metal is not worn nor varied its quality by plasma. Further, since the inside surface of the inner cylinder 49 is always renewed to a new surface, there is no worry about contamination due to varying in the quality of the inside surface.

FIG.11 shows an example of a plasma processing apparatus to which the present invention is applied, and the plasma processing apparatus is of an external energy supplying discharge type, and particularly of an induction coupling discharge type and a magnetic field type. The reference character 120 is an electrode and the reference character 48 is a high frequency power source. A process chamber 4 of a vacuum chamber has a ceramic plate 124, an inner cylinder 122, a sample table 10 for mounting a wafer 11. Further, there are provided a heater 166 and a gas flow passage 130 for supplying a gas to the gap to perform temperature control by heating and cooling the ceramic plate 124. A gas supply system has a gas source, a pressure control valve, a pressure detector, a pressure command instruction means and a controller, and operates so as to maintain the pressure P in the gap at a preset value. The temperature T_0 of the ceramic plate 124 is controlled by a temperature controller through the heater 126 and the temperature T of the inner cylinder 122 can be kept to a desired value.

With such a construction, by maintaining the temperature of the inner cylinder 122 at a preset value, it is possible to perform a stable plasma processing by the same action described in the above embodiment. Further, it is possible to obtain the effect that the metal is not worn nor varied its quality by plasma. Further, since the inside surface of the inner cylinder is always renewed to a new surface, there is no worry about contamination due to varying in the quality of the inside surface.

In each of the embodiments described in FIG.8 to FIG.11, it is preferable that a non-magnetic and non-metallic material is used for the material of the inner cylinder in order to decrease effect to the magnetic field and the electric field.

The present invention can be applied not only to a plasma etching apparatus but also to a CVD apparatus or a spattering apparatus.

Further, application of the present invention is not limited to the case where a process is stabilized by maintaining the temperature of the inner cylinder to a preset value. The present invention can be also applied to, for example, a case where initial process change for a lot is corrected by intentionally changing the temperature of the inner cylinder at the initial stage of the lot. That is, it is possible to stabilize a process by improving the temperature controllability for the inner cylinder.

The apparatuses described in FIG.1 to FIG.11 are used as follows.

Before starting operation of the apparatus, it is checked whether or not the temperature of the inner cylinder can be controlled to a desired temperature.

Firstly, inside of the process chamber 4 is evacuated to a preset pressure by action of the vacuum pump. Then the heater is operated. The inner cylinder is heated by heat generation of the heater. During this period, a heat transfer gas is supplied to the gap and the gas pressure in the gap is adjusted to a preset pressure. That is, heating of the inner cylinder is performed by utilizing heat transfer of the heat transfer gas supplied to the gap. The temperature of the heated inner cylinder is directly or indirectly detected and controlled to a desired temperature. By doing so, it can be confirmed that the temperature of the inner cylinder can be controlled to the desired temperature. If the temperature of the inner cylinder cannot be controlled to the desired temperature, the heater is stopped to operate and the heat transfer gas is stopped to be supplied to the gap. And cause of the trouble is checked and repaired.

In the above case, one wafer is introduced into the process chamber using a transfer machine which is not shown in the figures. The introduced wafer is transferred from the transfer machine to the sample table and mounted on a sample mounting surface so that the surface opposite to the surface to be processed is facing the sample mounting surface. In the apparatuses described in FIG.1 to FIG.11, a temperature control means having cooling function is provided to the sample table. In a CVD apparatus or a spattering apparatus which requires to heat a wafer during processing, a temperature control means having heating function is provided to the sample table. The wafer mounted on the sample mounting surface of the sample table is held on the sample table by a mechanical clamping means utilizing a spring force or gravitational force, an electrostatic attracting means, a vacuum sucking means or the like.

Then, a process gas is introduced into the process chamber with a preset flow rate. A part of the process gas introduced in the process chamber is exhausted out of the process chamber by the operating vacuum pump. By doing so, the pressure inside the process chamber is adjusted to a processing pressure of the wafer.

Under such a condition, the process gas in the process chamber is changed to a plasma by discharge. The surface to be processed of the wafer mounted on the sample mounting surface of the sample table is processed by plasma. During processing, the temperature of the wafer is controlled at a preset temperature.

During processing, the temperature of the inner cylinder is monitored continuously or when required. The monitored temperature is compared with a preset desired temperature , and the temperature of the inner cylinder is controlled to the desired temperature based on the result of the comparison. The temperature control of the inner cylinder is performed by adjusting the pressure of the heat transfer gas in the gap between the inner cylinder and the outer cylinder or by adjusting the temperature of the outer cylinder through adjusting generating heat of the heater. The pressure adjusting of the heat transfer gas in the gap between the inner cylinder and the outer cylinder is performed by adjusting the supply flow rate or the pressure of the heat transfer gas supplied to the gap.

In general, plural wafers are continuously processed one by one. In such a case, the temperature of the inner cylinder is monitored while processing one wafer among them until processing for the all plural wafers is completed to control the temperature to the desired temperature. For example, when a trouble occurs in the temperature monitoring of the inner cylinder or when the temperature of the inner cylinder cannot be controlled to the desired temperature, it is judged that the processing characteristic of the wafer cannot be maintained stable and the wafer processing is stopped. During stopping period, effort to solve the problem is made. Then, the successive process for plural wafers is re-started.

The fact that a trouble occurs in the temperature monitoring of the inner cylinder or that the temperature of the inner cylinder cannot be controlled to the desired temperature is noticed to an operator by output of some kind of alarm through the controller. With the alarm, the operator solves the trouble and re-starts the wafer processing. by monitoring the factor in regard to the temperature control of the inner cylinder, the history until stopping of the wafer processing can be checked and consequently the search of the cause and the repairing method can be performed properly and fast.

A cleaning process is performed for the inside of the process chamber. The process is performed by wiping the inside surface of the process chamber such as the surface of the inner cylinder and the surfaces of parts arranged inside the process chamber such as the sample table, or utilizing a cleaning gas plasma. The process is performed before a wafer processing, in the intervals between processings, or after completion of a wafer processing.

In a case of performing cleaning process by wiping, it is checked whether the temperature of the inner cylinder can be controlled during a period after completion of the cleaning processing and before a starting of a wafer processing. On the other hand, in a case of performing cleaning process by utilizing plasma, it is checked whether the temperature of the inner cylinder can be controlled during the cleaning processing or during a period after the cleaning process and before a starting of a wafer processing.

Further, a discharge running-in (seasoning) process is performed for the inside of the process chamber. The seasoning process is performed before starting a wafer processing in a day, or during a period after completion of a cleaning processing and before starting of a wafer processing. In this case, it may be checked during the seasoning process whether the temperature of the inner cylinder can be controlled or not.

In order to stabilize the characteristic of plasma processing over time, it is necessary to control the temperature of the inner cylinder to a temperature corresponding to a wafer processing condition. Here, as the wafer processing conditions there are quality of film to be processed, kind of processing gas, condition of discharge, type of discharge and so on.

Therefore, wafer processing conditions are input to the controller of the processing apparatus from a higher level controlling unit or an operator. The controller has been input a temperature of the inner cylinder corresponding to each of the wafer processing conditions. In the controller, a temperature of the inner cylinder corresponding to the input wafer processing condition is selected and set as a control temperature. On the other hand, a detected and monitored temperature of the inner cylinder is input in the controller. The detected and monitored temperature is compared with the control temperature, and the temperature of the inner cylinder is controlled to the control temperature based on the result of comparison.

Further, in a case where the wafer is, for example, of a multi-layer film structure, the temperature of the inner cylinder may be controlled to a temperature corresponding to each set of quality of film, kind of process gas, condition of discharge and so on. By ding so, the characteristic of plasma processing can be finely stabilized over time.

In a case where a wafer processing performance is varied during one lot processing after a running-in discharge (seasoning) process, the temperature of the inner cylinder may be varied along a desired temperature pattern in order to make the processing performance uniform.

Although the above description has been made on the temperature control of the inner cylinder inside the chamber, the present invention can be similarly applied to the temperature control of the sample table cover arranged around the sample table.

FIG.14 is a cross-sectional view showing an embodiment of a sample table cover portion of a plasma processing apparatus to which the present invention is applied. A liquid for temperature control is recirculated inside a sample table 10, and an insulator is applied onto the surface of the sample table maintained at a desired temperature, and a sample 11 is attracted to the sample table 10 by an electrostatic force using an direct current power source 54 for electrostatic chuck under condition discharge exists in the processing chamber. A heat transfer gas, for example, helium gas is introduced between the sample 11 and the sample table 10 in order to increase thermal conductance. A sample table cover made of an insulator such as alumina or the like or a resistive material such as SiC or the like is arranged in the upper portion of the sample table 10 to prevent discharge of undesired metals when the metallic sample table 10 is exposed to a plasma. The temperature of the sample table cover is raised since ions and radicals in the plasma are collide with the surface of the sample table cover 50. When the temperature of the sample table cover 50 near the sample is varied, there is a disadvantage in that chemical-physical reaction is varied and consequently the processing characteristic of sample is varied. Therefore, a gas sealing means 55, for example, an O-ring is provided between the sample table 10 and the sample table cover 50, and a heat transfer gas is introduced between the sample table 10 and the sample table cover 50. The pressure control and its related system are the same as in the case of the inner cylinder. Although the heat transfer gas for cooling a sample is also used for the heat transfer gas for cooling the sample table cover in FIG.14, it is no need to say that the gas may be separately supplied.

According to the present invention, the temperature of the inner cylinder which directly contacts to a plasma can be controlled, and the change in the characteristic of plasma processing can be controlled over time.

Further, according to the present invention, it is possible to provide a plasma processing apparatus and a plasma processing method having a stable plasma processing characteristic which can prevent yielding a heavy metal contamination source caused by a non-magnetic and conductive metallic material composing a process chamber being worn and varied its quality by plasma, and under a condition that the wall surface of the process chamber is not chemically corroded by the reaction gas used inside the process chamber.

Claims

1. A plasma processing apparatus comprising a plasma generating unit (1), a process chamber (4) capable of reducing its inside pressure, a process gas supply unit (13) for supplying a gas to the process chamber (4), a specimen table (10, 47) for holding a specimen (11), and a vacuum pumping unit (44), wherein

   said process chamber (44) comprises an outer cylinder (5, 42, 91, 114, 124) having capability of withstanding reduced pressure, an inner cylinder (6, 49, 92, 112, 122) arranged inside said outer cylinder through a gap, (14, 50) and temperature controlling means (15, 21, 22, 23, 51, 116, 126) for maintaining the temperature of said inner cylinder within a given temperature range.

2. A plasma processing apparatus comprising a plasma generating unit (1), a process chamber (4) capable of reducing its inside pressure, a process gas supply unit (13) for supplying a gas to the process chamber (4), a specimen table (10) for holding a specimen (11), and a vacuum pumping unit (44), wherein

   said process chamber (4) comprises an outer cylinder (5, 42, 91, 114, 124) having capability of withstanding reduced pressure, an inner cylinder (6, 49, 92, 112, 122) arranged inside said outer cylinder through a gap (14, 50), temperature control-

ling means (15, 21, 22, 23, 51, 116, 126) arranged in said outer cylinder, and heat transmission means for transmitting heat between said outer cylinder and said inner cylinder arranged is said gap.

3. A plasma processing apparatus comprising a plasma generating unit (1), a process chamber (4) capable of reducing its inside pressure, a process gas supply unit (13) for supplying a gas to the process chamber (4), a specimen table (10) for holding a specimen (11), and a vacuum pumping unit (44), wherein

said process chamber comprises an outer cylinder (5, 42, 91, 114, 124) having capability of withstanding reduced pressure, a non-magnetic inner cylinder (6, 49, 92, 112, 122) arranged inside said outer cylinder through a gap (14, 50), temperature controlling means (15, 21, 22, 23, 51, 116, 126) arranged in said outer cylinder and heat transmission means for transmitting heat between said outer cylinder and said inner cylinder arranged in said gap.

4. A plasma processing apparatus comprising a plasma generating unit (1), a process chamber (4) capable of reducing its inside pressure, a process gas supply unit (13) for supplying a gas to the process chamber (4), a specimen table (10) for holding a specimen (11), and a vacuum pumping unit (44), wherein

said process chamber comprises an outer cylinder (5, 42, 91, 114, 124) having capability of withstanding reduced pressure, a non-magnetic inner cylinder (6, 49, 92, 112, 122) arranged inside said outer cylinder through a gap (14, 50), and temperature controlling means (15, 21, 22, 23, 51, 116, 126) for maintaining the temperature of said inner cylinder within a given temperature range.

5. A plasma processing apparatus according to any one of claim 1 to claim 4, wherein said temperature controlling means comprises a heater provided in said outer cylinder, the temperature of said outer cylinder being adjusted to a temperature from room temperature to 350 °C using said heater.

6. A plasma processing apparatus according to any one of claim 1 to claim 4, wherein said temperature controlling means comprises a flow passage (15) for recirculating fluid in said outer cylinder, the temperature of said outer cylinder being adjusted to a temperature from 0°C to 150 °C by recirculating a temperature controlled fluid in said flow passage.

7. A plasma processing apparatus according to any one of claim 2 and claim 3, wherein said heat transmission means comprises a heat transmitting gas supply system for introducing a heat transmitting gas into the gap between said outer cylinder and said inner cylinder.

8. A plasma processing apparatus according to claim 7, wherein said heat transmitting gas supply system comprises pressure controlling means for maintaining the pressure in said gap to a given pressure.

9. A plasma processing apparatus according to any one of claim 2 and claim 3, wherein a metallic flexible member used as said heat transmission means is arranged in said gap between said outer cylinder and said inner cylinder, said metallic flexible member being contacted to said outer cylinder and said inner cylinder by the spring force of said metallic flexible member.

10. A plasma processing apparatus according to claim 9, wherein said metallic flexible member is a corrugated plate.

11. A plasma processing apparatus according to any one of claim 1 to claim 4, wherein said inner cylinder is detachable from said outer cylinder.

12. A plasma processing apparatus according to any one of claim 1 to claim 4, wherein said inner cylinder is made of a material selected from the group of ceramic, carbon, silicon, quartz and metal.

13. A plasma processing apparatus according to claim 12, wherein said inner cylinder is made of a ceramic and having thickness of 2 mm to 10 mm.

14. A plasma processing apparatus according to claim 12, wherein said inner cylinder is made of a ceramic selected from the group of Al_2O_3 and SiC.

15. A plasma processing apparatus according to claim 12, wherein said inner cylinder is made of aluminum.

16. A plasma processing apparatus comprising a plasma generating unit (1) of external energy supply discharge type, a process chamber (4), a unit (13) for supplying a process gas to said process chamber, a specimen table (10) for holding a specimen (11) in said process chamber, and a unit (44) for evacuating and reducing said process chamber, wherein

said process chamber comprises an outer cylinder (5, 42, 91, 114, 124) having capability of withstanding reduced pressure, an inner cylinder (6, 49, 92, 112, 122) arranged inside said outer cylinder through a gap (14, 50), and temperature controlling and maintaining means (15, 21, 22, 23, 51, 116, 126) for maintaining the temperature of said inner cylinder to a given temperature through said

outer cylinder, said inner cylinder being made of a non-magnetic material.

17. A plasma processing apparatus according to claim 16, wherein said plasma generating unit is of a discharge type selected from the group of induction discharge type, magnetic-field applied discharge type and microwave discharge type.

18. A plasma processing apparatus comprising a plasma generating unit (1), a process chamber (4) capable of reducing its inside pressure, a process gas supply unit (13) for supplying a gas to the process chamber, a specimen table (10) for holding a specimen (11), and a vacuum pumping unit (44), wherein

said process chamber comprises an outer cylinder (5, 42, 91, 114, 124) having capability of withstanding reduced pressure, an inner cylinder (6, 49, 92, 112, 122) arranged inside said outer cylinder through a gap (14, 50), means (22) for detecting temperature of said inner cylinder, temperature controlling means (15, 21, 22, 23, 51, 116, 126) arranged in said outer cylinder, and heat transmission means for transmitting heat between said outer cylinder and said inner cylinder arranged in said gap.

19. A plasma processing apparatus comprising a plasma generating unit (1), a process chamber (4) capable of reducing its inside pressure, a process gas supply unit (13) for supplying a gas to the process chamber, a specimen table (10) for holding a specimen (11), a vacuum pumping unit (44) and a specimen table cover (50) arranged on the specimen table through a gap, temperature controlling means provided in said specimen table, and heat transmission means for transmitting heat between said specimen table and said specimen table cover arranged in said gap.

20. A plasma processing method of processing a specimen using a plasma processing apparatus comprising a plasma generating unit, a process chamber capable of reducing its inside pressure, a process gas supply unit for supplying a gas to the process chamber, a specimen table for holding a specimen, and a vacuum pumping unit, said process chamber comprises an outer cylinder having capability of withstanding reduced pressure, an inner cylinder arranged inside said outer cylinder through a gap, temperature controlling means arranged in said outer cylinder, and heat transmission means for transmitting heat between said outer cylinder and said inner cylinder arranged in said gap, wherein

plasma processing is performed to said specimen while the temperature of said inner cylinder is being kept within a given temperature range.

21. A plasma processing method of processing a specimen using a plasma processing apparatus comprising a plasma generating unit, a process chamber capable of reducing its inside pressure, a process gas supply unit for supplying a gas to the process chamber, a specimen table for holding a specimen, and a vacuum pumping unit, said process chamber comprises an outer cylinder having capability of withstanding reduced pressure, an inner cylinder arranged inside said outer cylinder through a gap, temperature controlling means arranged in said outer cylinder, and heat transmission means for transmitting heat between said outer cylinder and said inner cylinder arranged in said gap, wherein

said outer cylinder is made of a non-magnetic material, said inner cylinder being made of a non-magnetic material not containing heavy metals,

plasma processing being performed to said specimen while the temperature of said inner cylinder is being kept to an arbitrary temperature within a temperature range of 0°C to 350°C.

22. A plasma processing method of processing a specimen using a plasma processing apparatus comprising a plasma generating unit, a process chamber capable of reducing its inside pressure, a process gas supply unit for supplying a gas to the process chamber, a specimen table for holding a specimen, and a vacuum pumping unit, said process chamber comprises an outer cylinder having capability of withstanding reduced pressure, an inner cylinder arranged inside said outer cylinder through a gap, temperature controlling means arranged in said outer cylinder, and heat transmission means for transmitting heat between said outer cylinder and said inner cylinder arranged in said gap, wherein

said inner cylinder is made of a non-magnetic material not containing heavy metals, plasma processing being performed to said specimen while the temperature of said inner cylinder is being kept within a given temperature range,

said inner cylinder being exchanged with a new inner cylinder when the surface of said cylinder is worn off by a preset amount by plasma.

23. A plasma processing method of processing a specimen using a plasma processing apparatus comprising a plasma generating unit, a process chamber capable of reducing its inside pressure, a process gas supply unit for supplying a gas to the process chamber, a specimen table for holding a specimen, and a vacuum pumping unit, said process chamber comprises an outer cylinder having capability of withstanding reduced pressure, an inner cylinder arranged inside said outer cylinder through a gap, temperature controlling means

arranged in said outer cylinder, and heat transmission means for transmitting heat between said outer cylinder and said inner cylinder arranged in said gap, wherein

temperature of said inner cylinder is monitored during any one of periods before starting of processing a specimen, during processing a specimen and before starting of and during processing a specimen, and the specimen is not processed if the temperature of said inner cylinder is beyond a given temperature range.

24. A plasma processing method of processing a specimen using a plasma processing apparatus comprising a plasma generating unit, a process chamber capable of reducing its inside pressure, a process gas supply unit for supplying a gas to the process chamber, a specimen table for holding a specimen, and a vacuum pumping unit, said process chamber comprises an outer cylinder having capability of withstanding reduced pressure, an inner cylinder arranged inside said outer cylinder through a gap, temperature controlling means arranged in said outer cylinder, and heat transmission means for transmitting heat between said outer cylinder and said inner cylinder arranged in said gap, wherein

time varying fluctuation in plasma processing characteristic for plasma processing said specimen is suppressed by maintaining the temperature of said inner cylinder within a given temperature range.

25. A plasma processing method of processing a specimen using a plasma processing apparatus comprising a plasma generating unit utilizing a magnetic field and a microwave, a process chamber capable of reducing its inside pressure, a process gas supply unit for supplying a gas to the process chamber, a specimen table for holding a specimen, and a vacuum pumping unit, said process chamber comprises an outer cylinder having capability of withstanding reduced pressure, an inner cylinder arranged inside said outer cylinder through a gap, temperature controlling means arranged in said outer cylinder, and heat transmission means for transmitting heat between said outer cylinder and said inner cylinder arranged in said gap, wherein

time varying fluctuation in plasma processing characteristic for plasma processing said specimen is suppressed by maintaining the temperature of said inner cylinder within a given temperature range.

26. A plasma processing method comprising the steps of:

making a gas used for etching processing into a plasma;

performing etching processing of a specimen in a process chamber using said plasma; and

maintaining temperature of the wall of said process chamber to a temperature at which etching speed for each of different materials of said specimen is stabilized.

27. A plasma processing method according to claim 26, wherein when a plurality of said specimens are etching processed one by one, temperature of the wall of said process chamber is maintained to a temperature at which etching speed for each of different materials of said specimen is stabilized.

28. A plasma processing method according to any one of claim 26 and claim 27, wherein temperature of the wall of said process chamber is maintained to a temperature at which etching speeds of oxide film and resist of said specimen are respectively stabilized.

29. A plasma processing method according to claim 28, wherein temperature of the wall of said process chamber is maintained to a temperature at which at least etching speed for the resist among the etching speeds of the oxide film and the resist is stabilized, the etching speed of the resist varying depending on the temperature of the wall of said process chamber.

FIG. 1

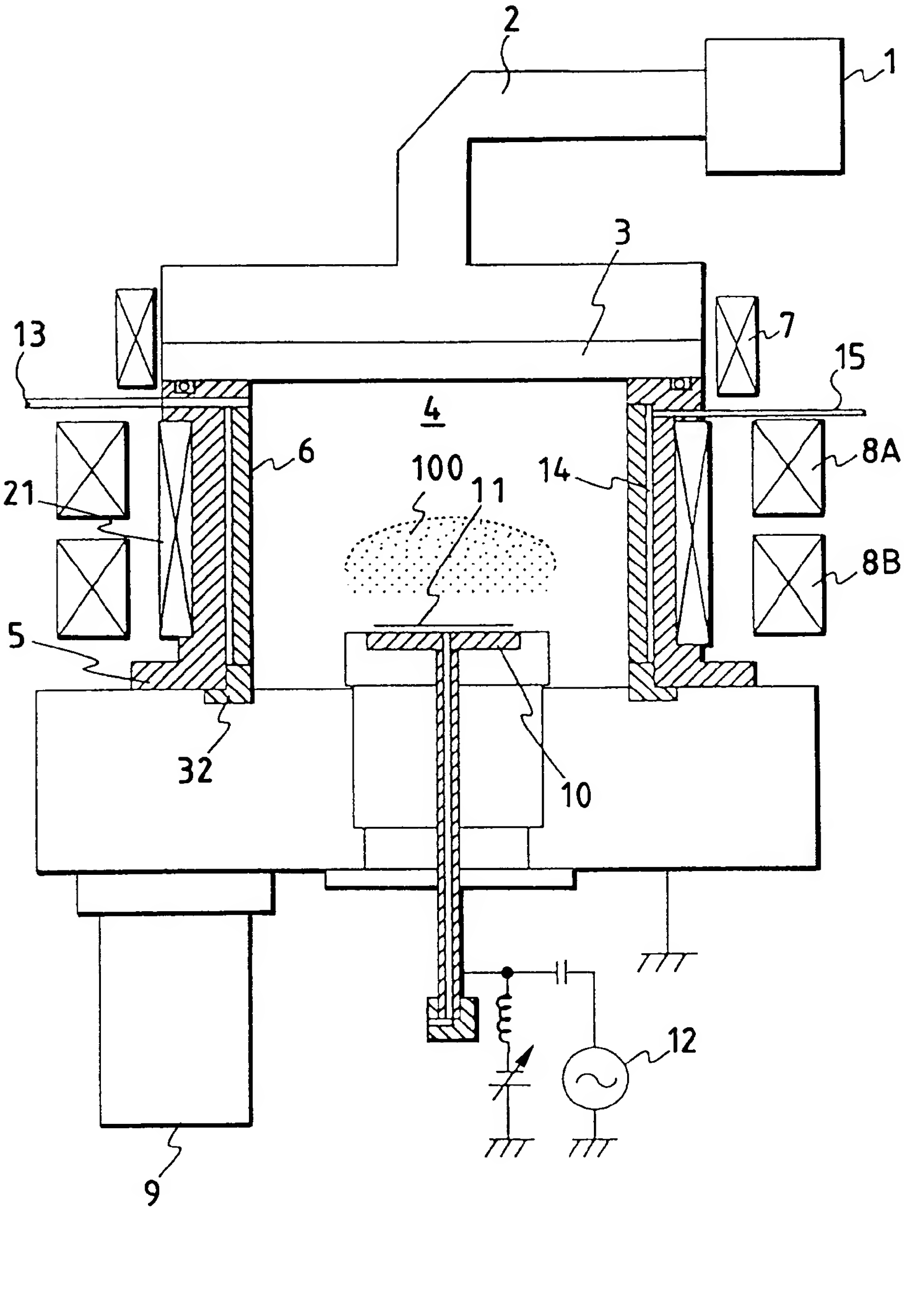


FIG. 2

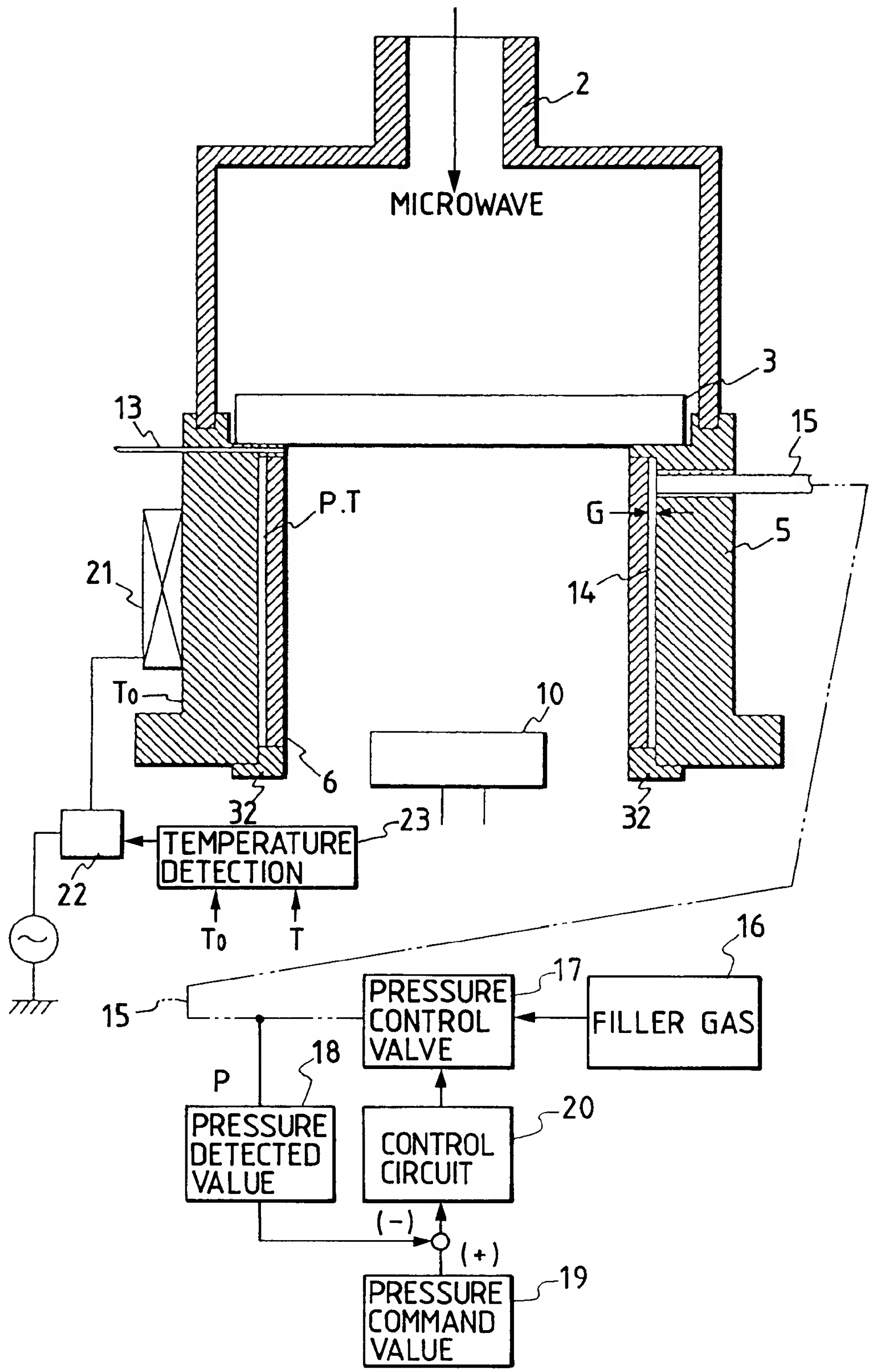

MICROWAVE
2
3
13
15
P.T
G
5
21
14
T0
10
6
32
23
32
TEMPERATURE DETECTION
22
T0
T
16
17
15
PRESSURE CONTROL VALVE
FILLER GAS
18
P
20
PRESSURE DETECTED VALUE
CONTROL CIRCUIT
(−)
(+)
19
PRESSURE COMMAND VALUE

FIG. 3

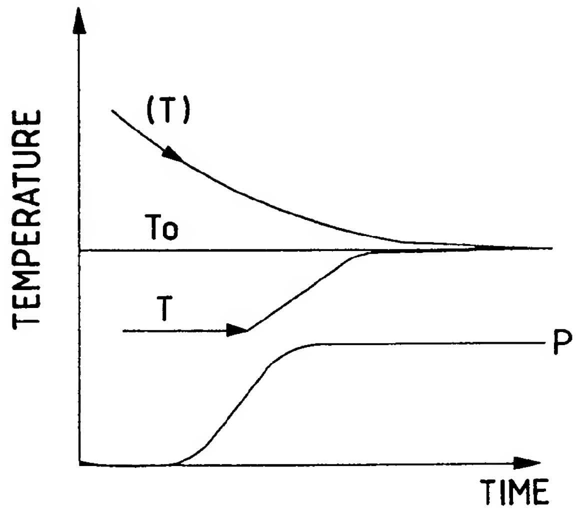


FIG. 4

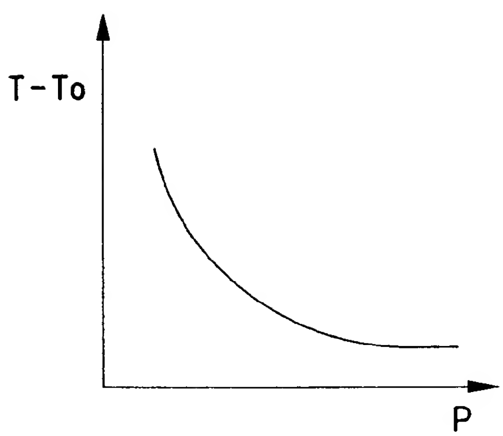


FIG. 5

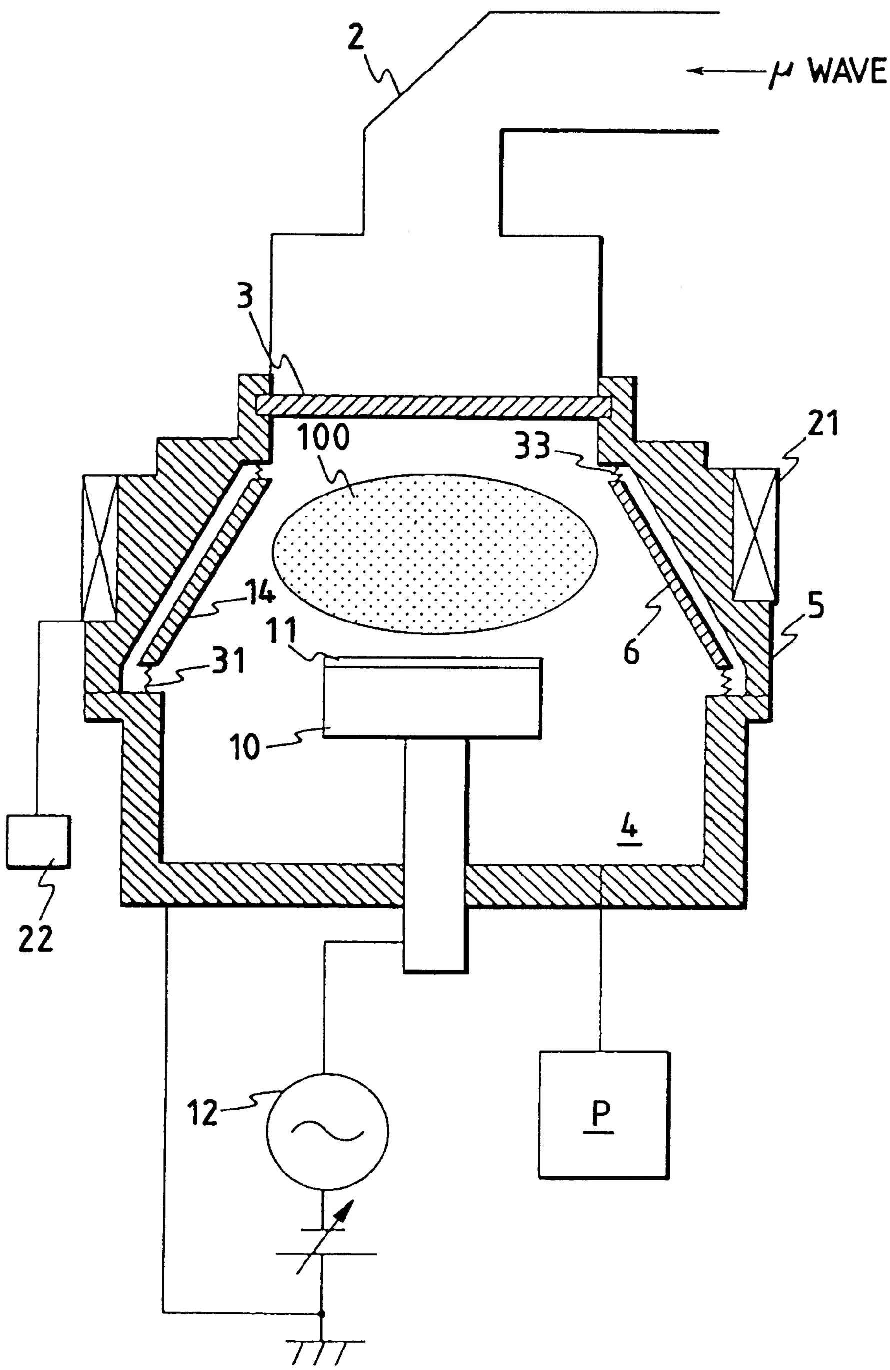


FIG. 6

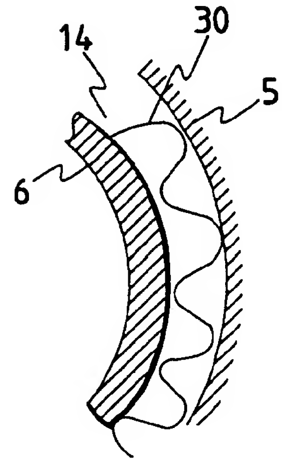

14
30
5
6

FIG. 7

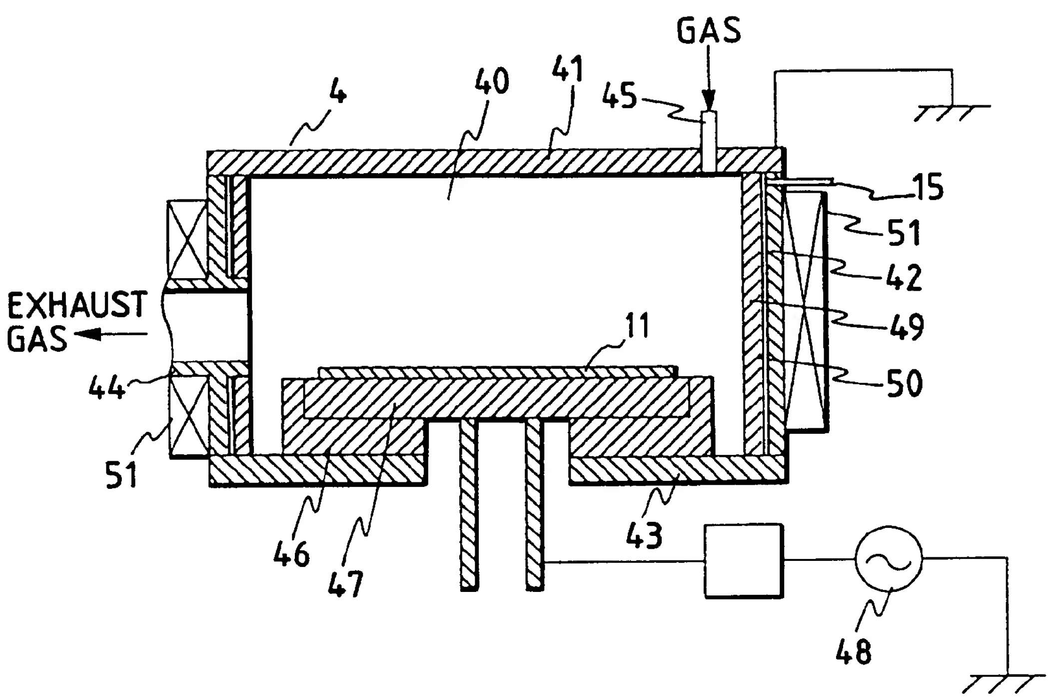

GAS
4
40
41
45
15
51
42
49
50
EXHAUST GAS
11
44
51
46
47
43
48

FIG. 8

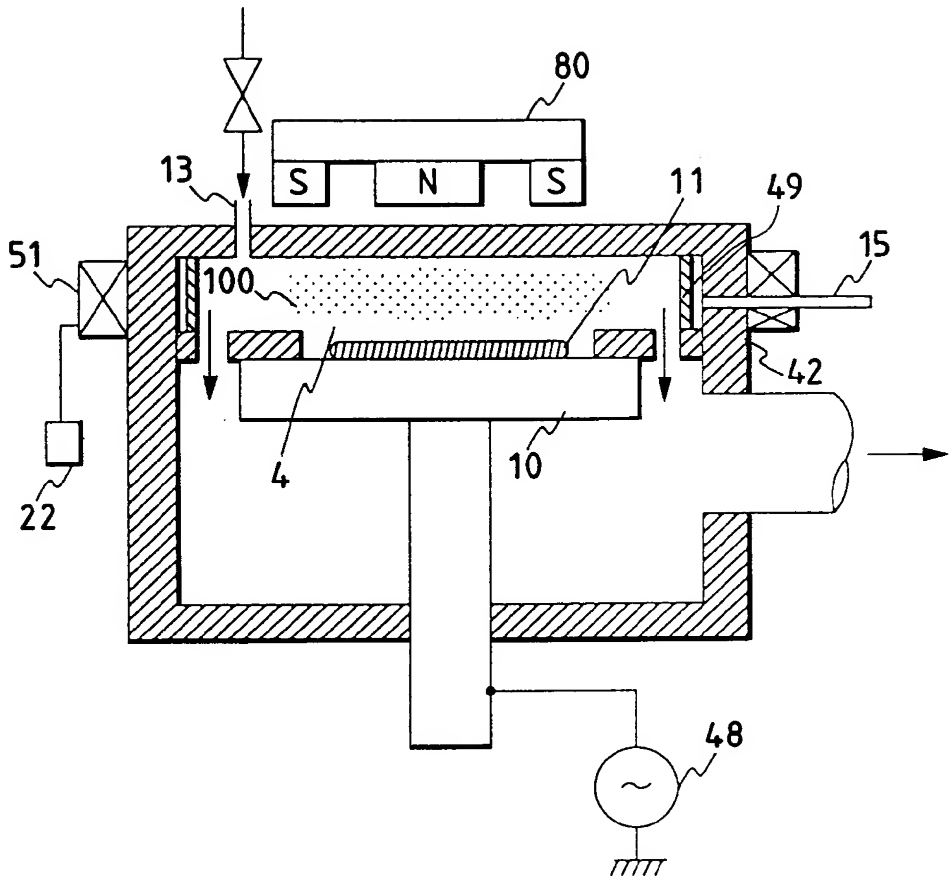

80
S
N
S
13
11
49
15
51
100
42
4
10
22
48

FIG. 9

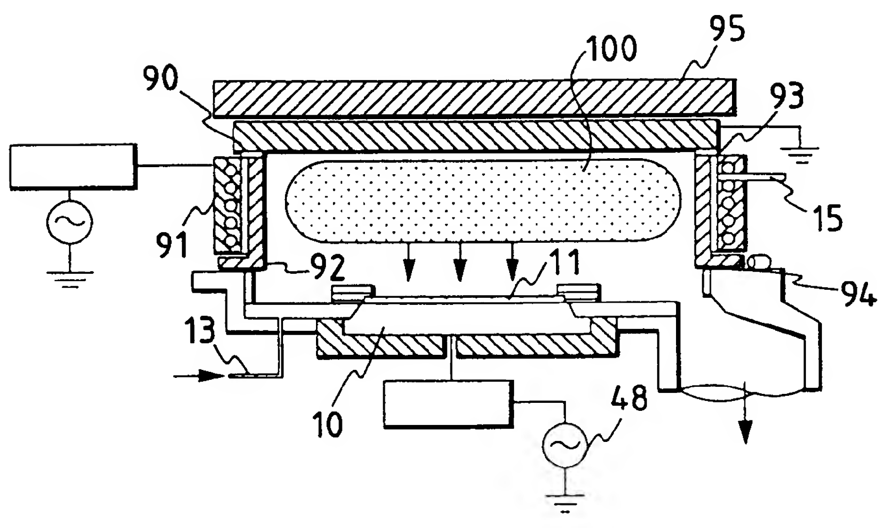

95
100
90
93
91
15
92
11
94
13
10
48

FIG. 10

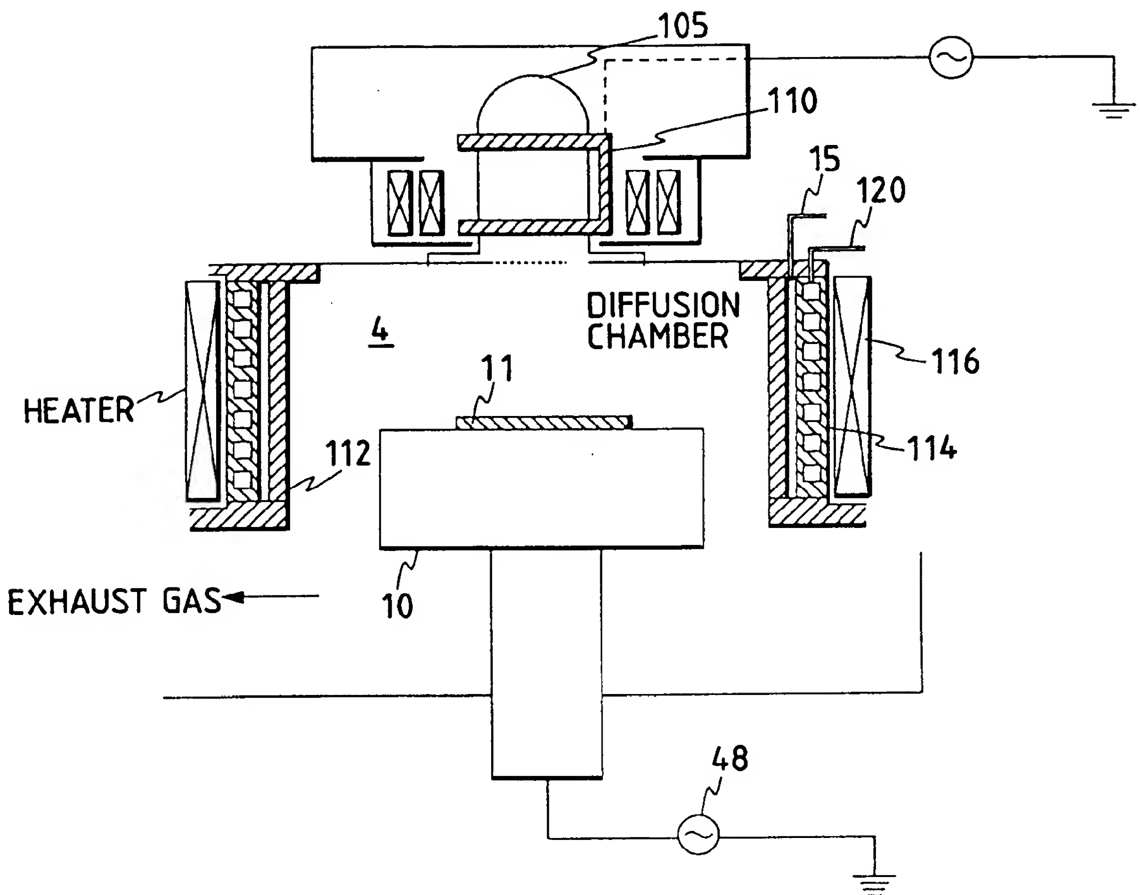

105
110
15
120
DIFFUSION CHAMBER
4
11
116
HEATER
112
114
EXHAUST GAS
10
48

FIG. 11

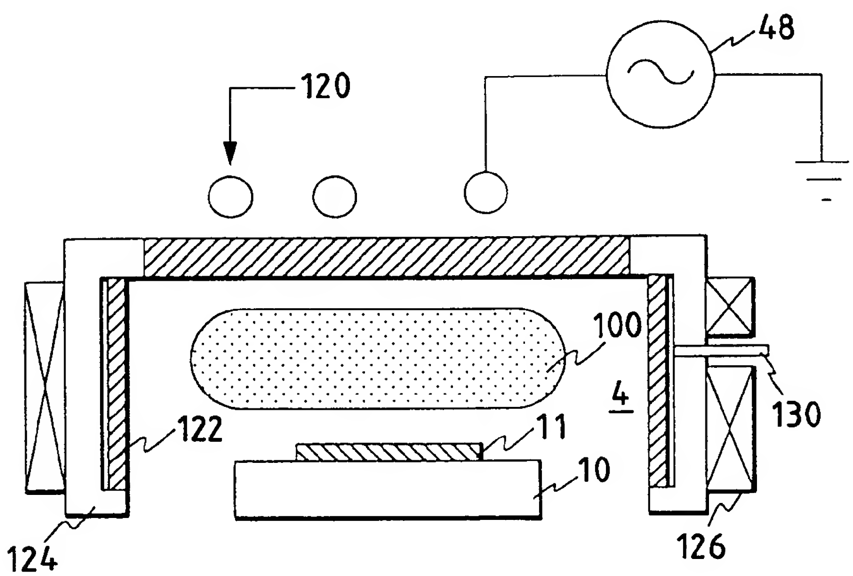

48
120
100
4
130
122
11
10
124
126

FIG. 12

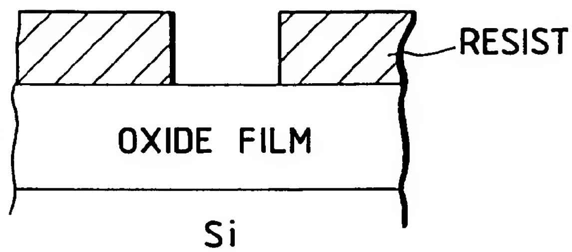

RESIST
OXIDE FILM
Si

FIG. 13

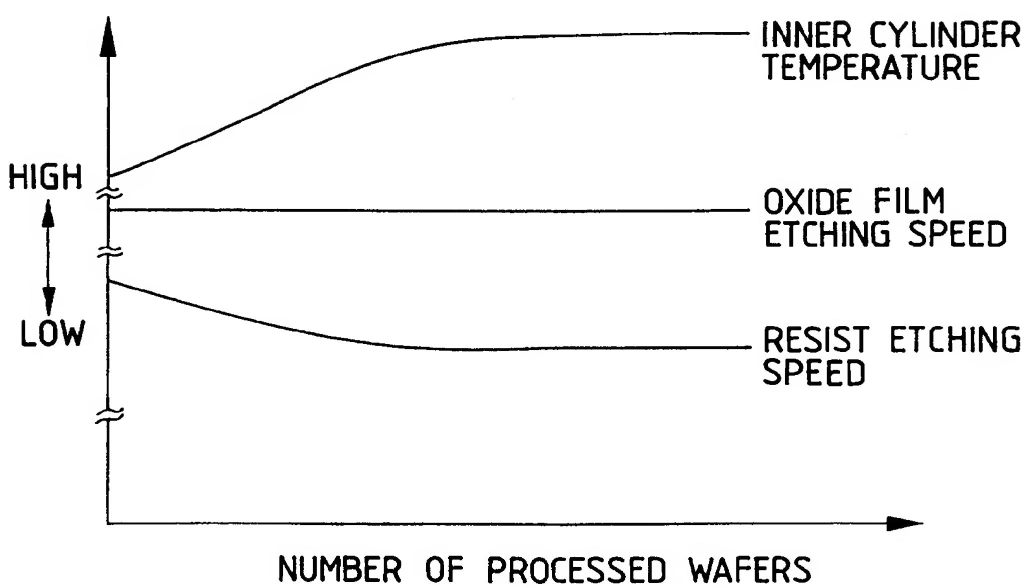
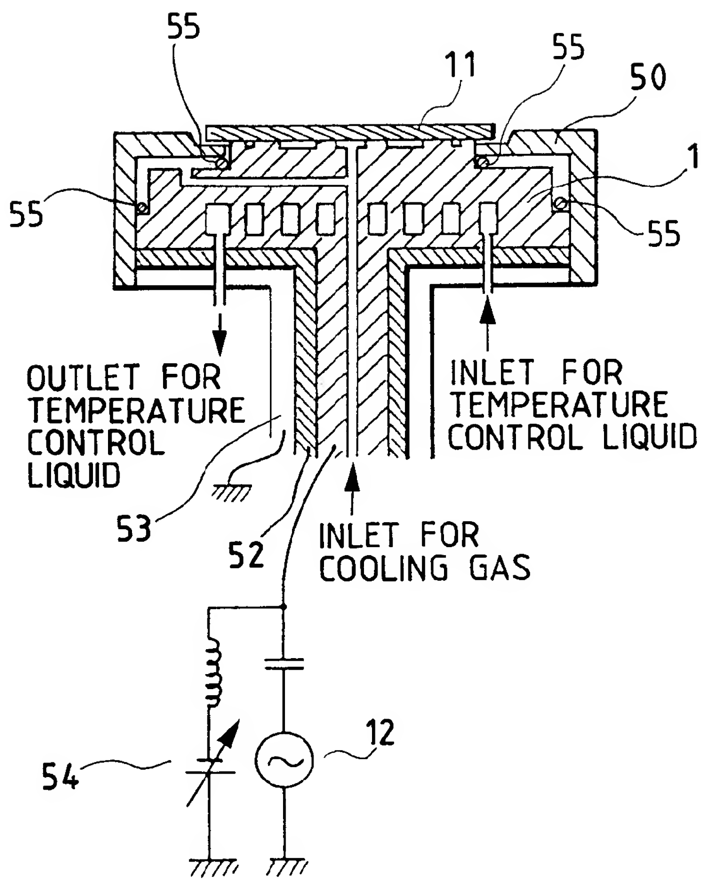

INNER CYLINDER TEMPERATURE
HIGH
OXIDE FILM ETCHING SPEED
LOW
RESIST ETCHING SPEED
NUMBER OF PROCESSED WAFERS

FIG. 14


55
11
55
50
10
55
55
OUTLET FOR TEMPERATURE CONTROL LIQUID
INLET FOR TEMPERATURE CONTROL LIQUID
53
52
INLET FOR COOLING GAS
54
12